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& Sustainability
SYMPOSIUM & EXHIBITION

Waste to Energy Potential – A High Concentration Anaerobic Bioreactor

Presenter: Scott Murphy & Rebecca Robbennolt
ARCADIS/Malcolm Pirnie
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ARCADIS MALCOLM PIRNIE

Report Documentation Page

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Introduction

- Renewable energy and landfill diversion key for Department of Defense.
- *The National Defense Authorization Act of 2010:*
  - 25% of energy needs from renewable energy sources by 2025.
- *Strategic Sustainability Performance Plan 2011*:
  - Divert 50% of non-hazardous solid waste from the waste stream by 2015.
  - 254 million tons of solid waste each year
- Some states have similar goals and objectives.
  - Organic waste collection programs exist in FL, CA, WA, AZ VA, MN, OH, PA, MD, and NC.
- Solid waste management an increasing challenge
  - high cost of landfill management,
  - transportation costs,
  - tipping fees, etc.
- ARCADIS' High Concentration Anaerobic Bioreactor (HCAB) process addresses these issues.

Anaerobic Digestion

- What does it do?
  - Offers sustainability by addressing renewable energy, waste diversion, and beneficial reuse
- How does it work?
  - Uses anaerobic digestion in an energy-efficient, minimum-capacity tank, resulting in high energy output
  - Uses the organic portion of solid waste (such as food waste, paper products, and agricultural waste) to fuel an anaerobic digestion process
  - bacteria consume approximately 50-70% of the solids placed in the bioreactor and, generate a biogas
- What do you get?
  - Biogas that can be used to generate electricity
  - Residual solids that can be used as a soil amendment

Anaerobic Digestion Steps

1. Solubilization & breakdown of complex organics by microbes in O_2 depleted environment
2. Complex microbes and fermentative bacteria break down organic carbon to VFAs
3. Acetogens break down VFAs to $CH_3CO_2^-$ and H_2^+
4. Acetoclastic methanogens break down $CH_3CO_2^-$ to CO_2 and H_2O
5. Hydrogeno-trophic methanogens convert the H_2 and CO_2 to CH_4

HCAB Timeline

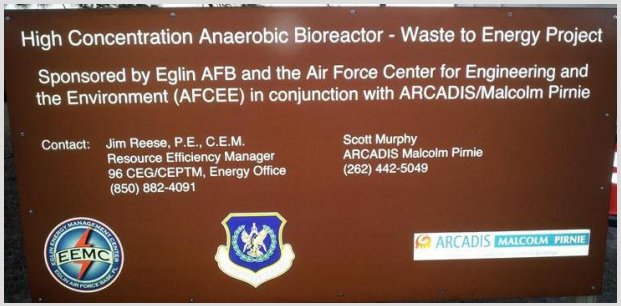
2005-07
Review
and
Concept

2006-07
Field pilot

2007
Bench
Studies
and Patent
Application

2010
Patent
Approved

2011
Initiate
Pilot
Study at
Eglin AFB



HCAB Operating Process

- What is the HCAB?
  - A unique combination of existing technologies. Advancements allow the reactor to be operated at high solids concentrations
- What is special about it?
  - Patented internal rake arm for solids control
  - High solids concentration feedstock
  - High volatile solids loading
- Practical features:
  - The process uses naturally occurring bacteria, also found in landfills, wastewater digesters
  - The equipment design is based on standard equipment
  - There is no need for the purchase of specialized spare parts

Eglin AFB Project Overview

- ARCADIS studied available waste streams at Eglin Air Force Base and determined the quantity and quality of the waste
- ARCADIS installed a pilot system capable of processing up to 700 pounds per day of organic waste
- A full scale system is planned, capable of processing municipal solid waste
- Currently the Pilot Study has been completed and design of the full-scale system is underway

HCAB Pilot Operation, Eglin AFB

August 2011 through March 2012

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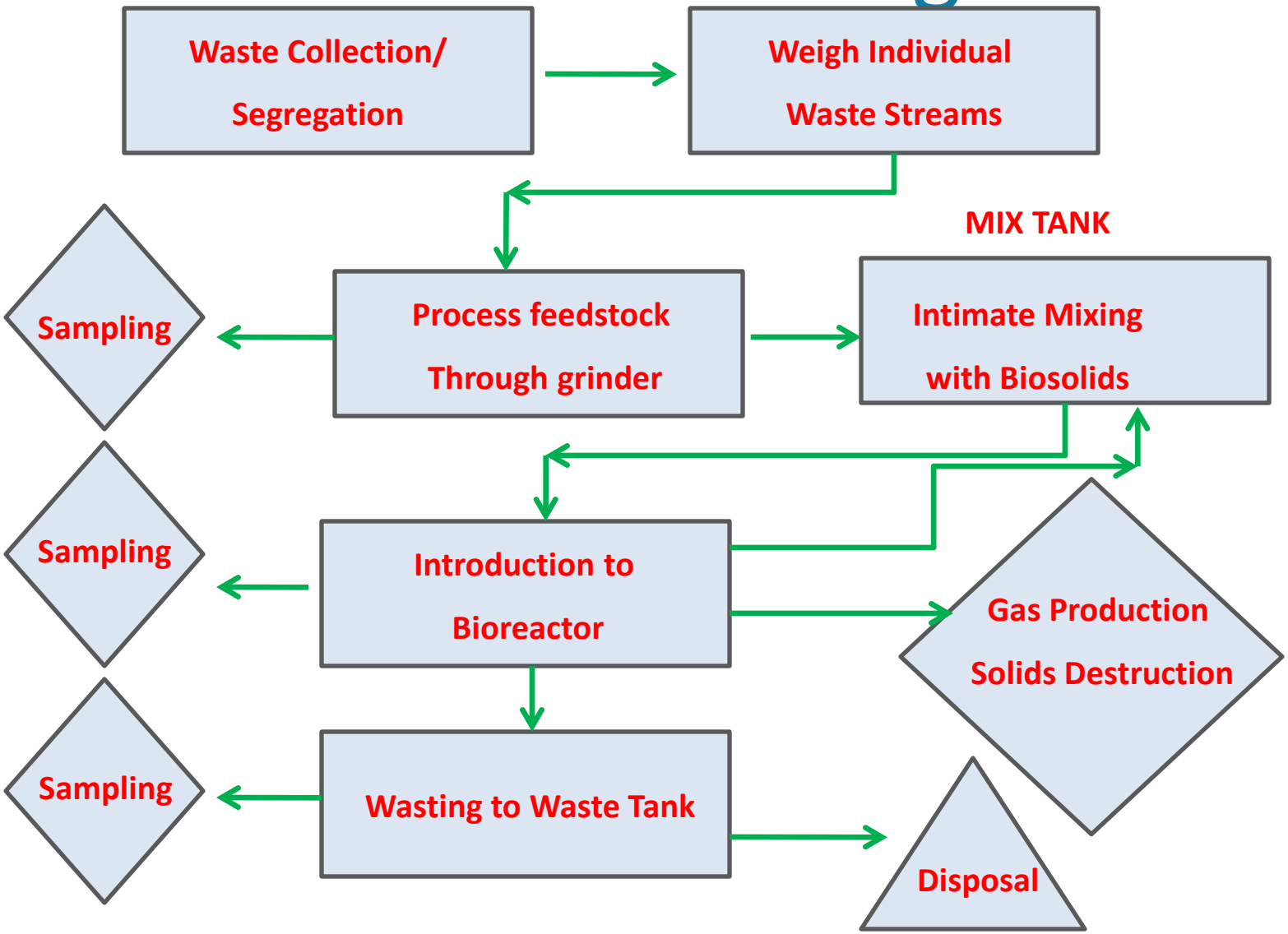
Objectives of the Demo

- Establish the inoculation/startup procedures
- Optimize presorting requirements
- Evaluate biogas quality
- Establish biogas pre-conditioning requirements
- Understand the cause of upset conditions
- Determine
  - optimal mixture of feedstock
  - biological kinetics at pseudo-steady state
  - optimal solids concentration
  - torque requirements for mixing
  - optimal operating temperature
  - solids and volatile solids destruction
  - biogas volume
  - nutrient value of waste sludge
  - composition of wastewater side streams

Process Flow Diagram



Pilot Plant

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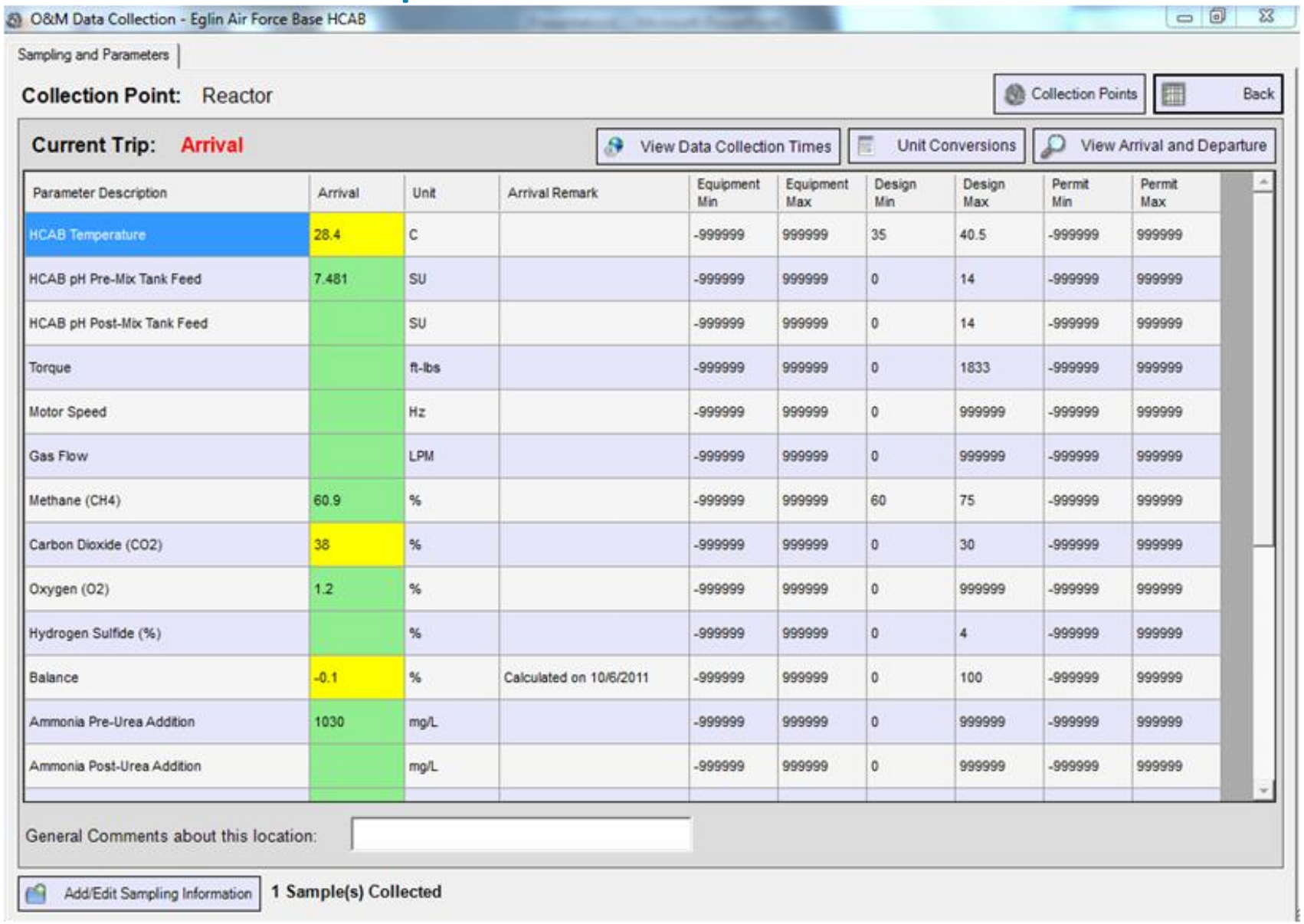
Field Measurement Summary

Mix Tank	Reactor	Waste Tank
pH	Methane	Load Cell Data
Temperature	Gas flow	
Load Cell Data	Torque	
Feedstock Density	Motor speed	
	Solids Density	
	pH	
	Temperature	
	Pump status	

Snapshot - Data Collection



Parameter Description	Arrival	Unit	Arrival Remark	Equipment Min	Equipment Max	Design Min	Design Max	Permit Min	Permit Max
HCAB Temperature	28.4	C		-999999	999999	35	40.5	-999999	999999
HCAB pH Pre-Mix Tank Feed	7.481	SU		-999999	999999	0	14	-999999	999999
HCAB pH Post-Mix Tank Feed		SU		-999999	999999	0	14	-999999	999999
Torque		ft-lbs		-999999	999999	0	1833	-999999	999999
Motor Speed		Hz		-999999	999999	0	999999	-999999	999999
Gas Flow		LPM		-999999	999999	0	999999	-999999	999999
Methane (CH4)	60.9	%		-999999	999999	60	75	-999999	999999
Carbon Dioxide (CO2)	38	%		-999999	999999	0	30	-999999	999999
Oxygen (O2)	1.2	%		-999999	999999	0	999999	-999999	999999
Hydrogen Sulfide (%)		%		-999999	999999	0	4	-999999	999999
Balance	-0.1	%	Calculated on 10/6/2011	-999999	999999	0	100	-999999	999999
Ammonia Pre-Urea Addition	1030	mg/L		-999999	999999	0	999999	-999999	999999
Ammonia Post-Urea Addition		mg/L		-999999	999999	0	999999	-999999	999999

Feedstock Addition

Operational Summary

Feedstock	Mix Tank	Bioreactor	Waste Tank
Collection	Biosolids Addition	Waste/ Recycle	Waste Solids Storage
Preparation	Mixing	Biogas Production	Sampling
Grinding		Sampling	
Sampling		Field Analysis Sampling	

Composition Summary

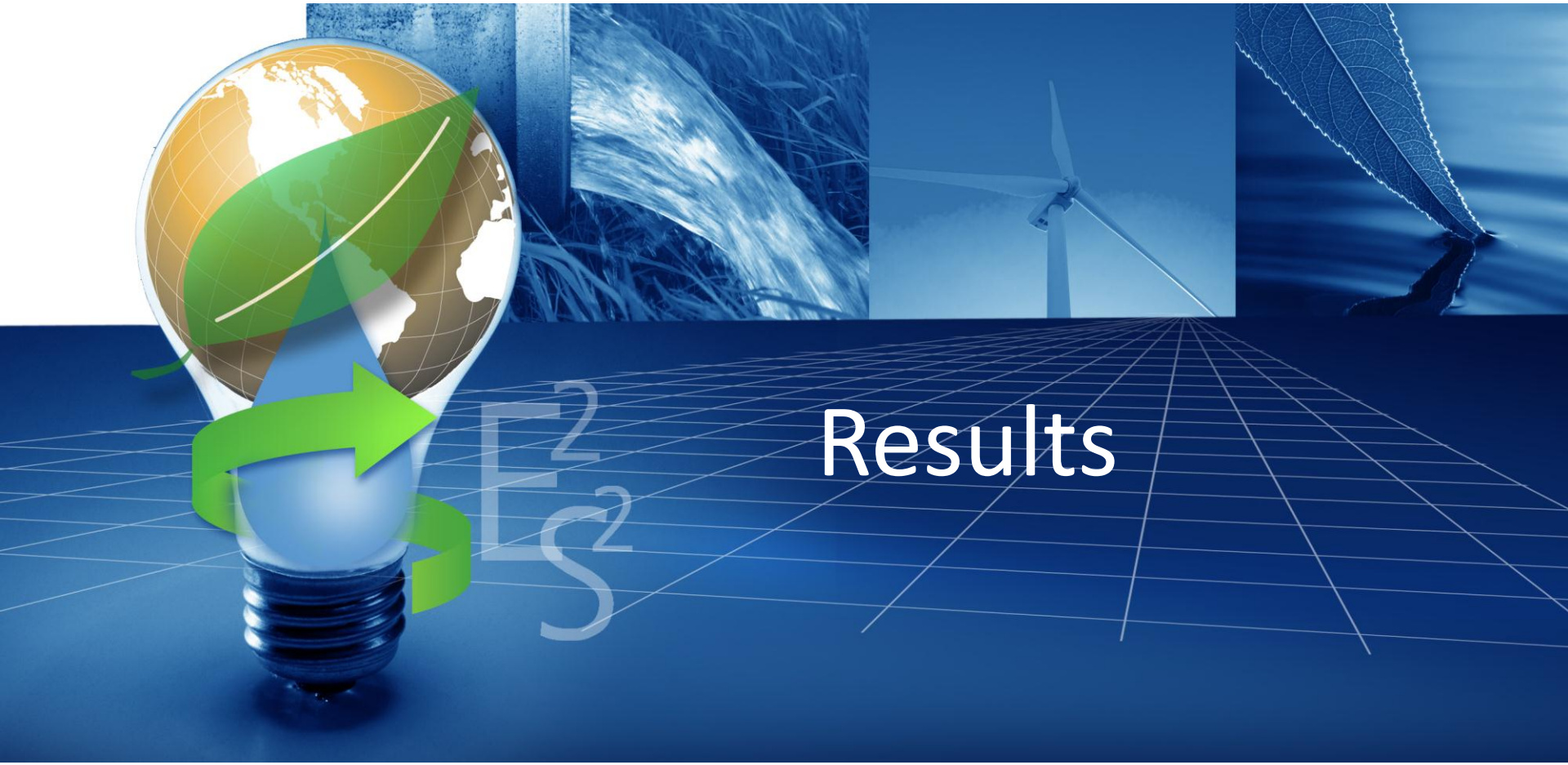
• Composition testing determined the effects of different waste streams on the overall chemistry.

<u>Composition 1</u>

- Food Waste
- Paper Towel Waste

<u>Composition 2</u>

- Food Waste
- Paper Towel Waste
- Food Grade Grease
- Stable Waste
- Wood Waste



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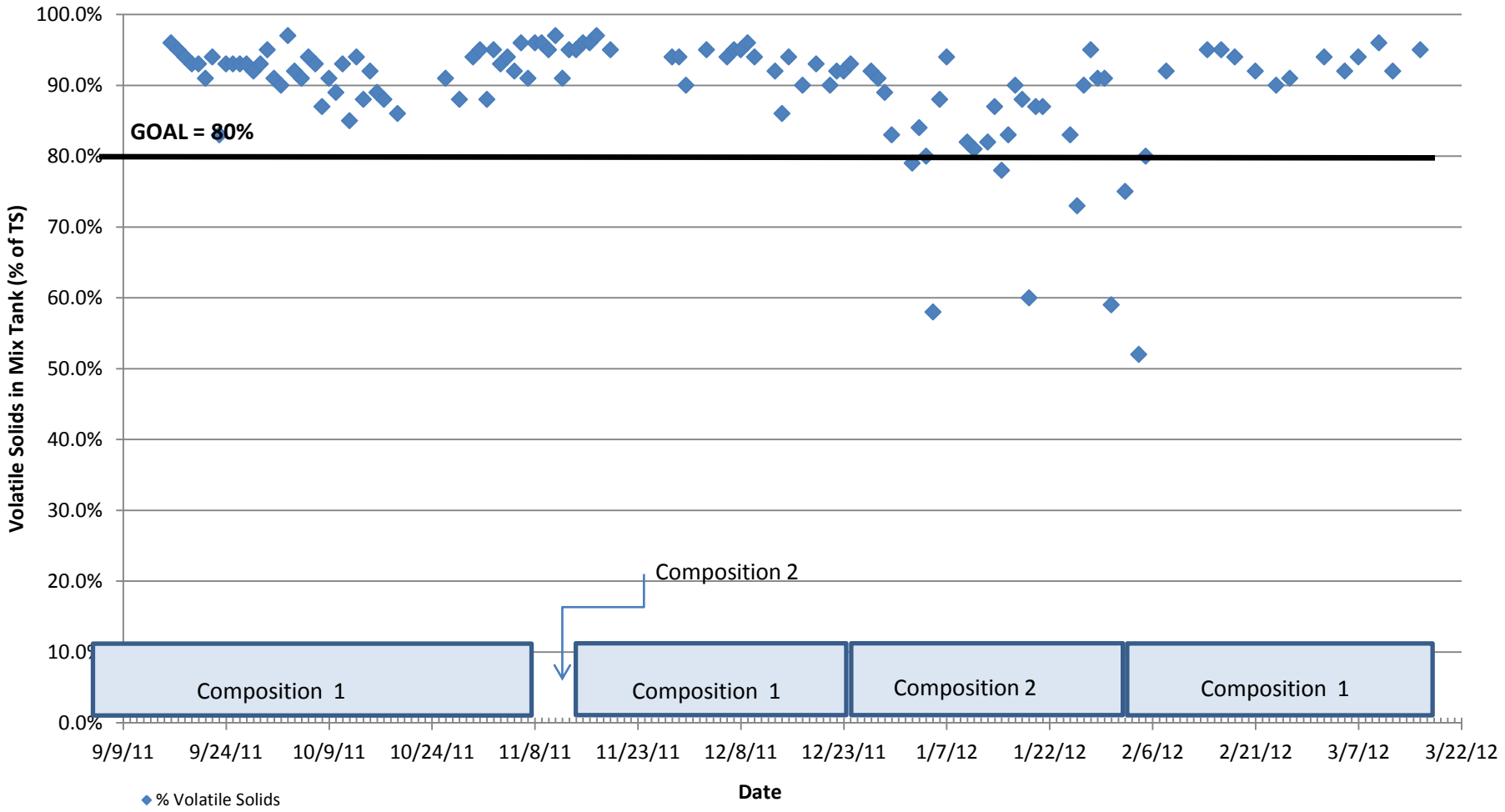
Data Compilation

- Measure actual results against the target goals & objectives
- Extrapolate the results to a full scale system
- Determine actual energy output potential for a full scale system

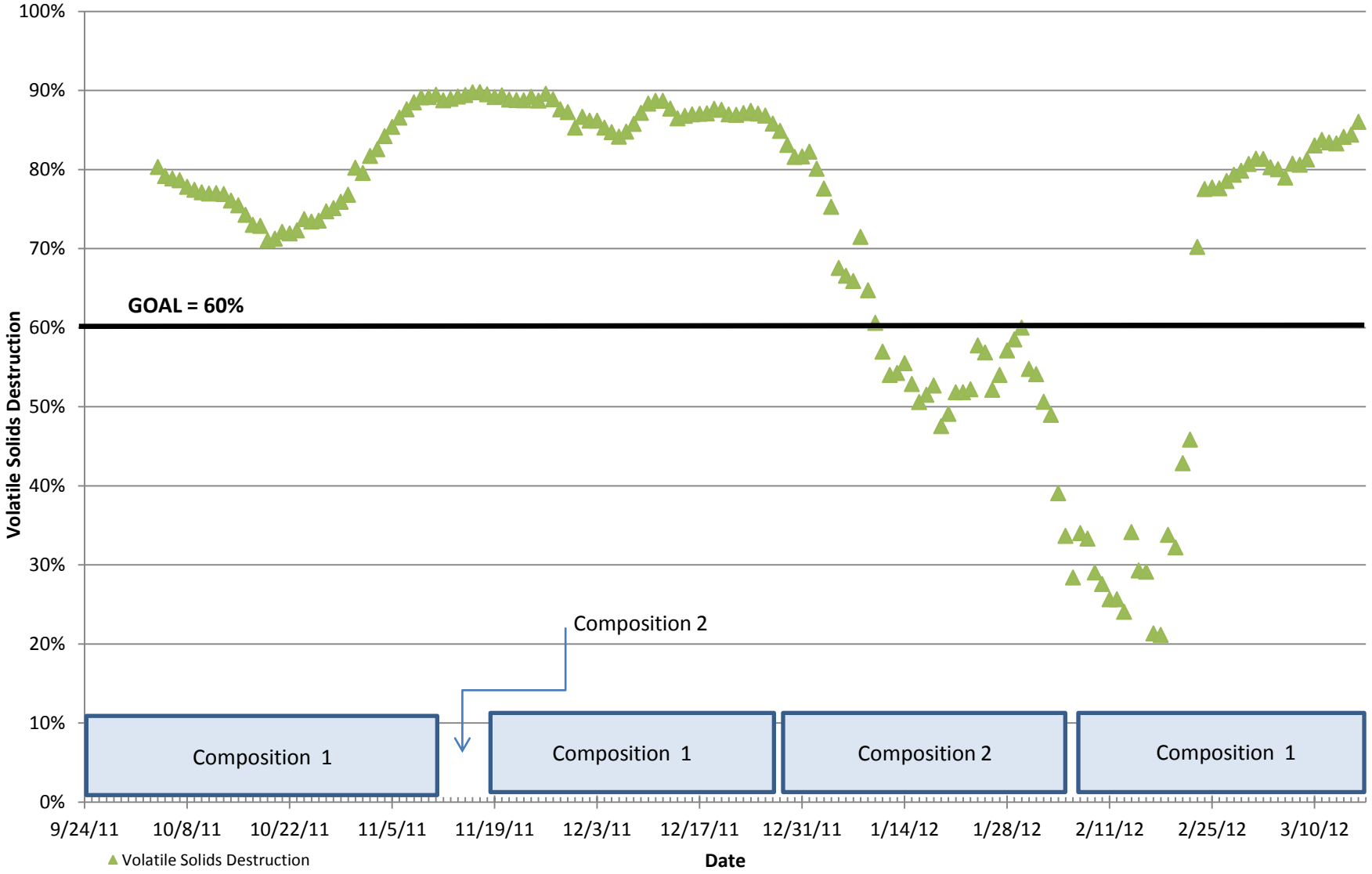
Volatile and Total Solids

- Volatile Solids = food for microbes
  - high VS loading and corresponding high VS destruction = higher efficiency
- Volatile Solids in Feedstock
  - Goal 80 %
  - Actual for Composition 1: Average 92 %
  - Actual for Composition 2: Average 70%
- Volatile Solids Destruction in bioreactor
  - Goal 60 %
  - Actual for Composition 1: Average 79.4%
  - Actual for Composition 2: Average 76.8%

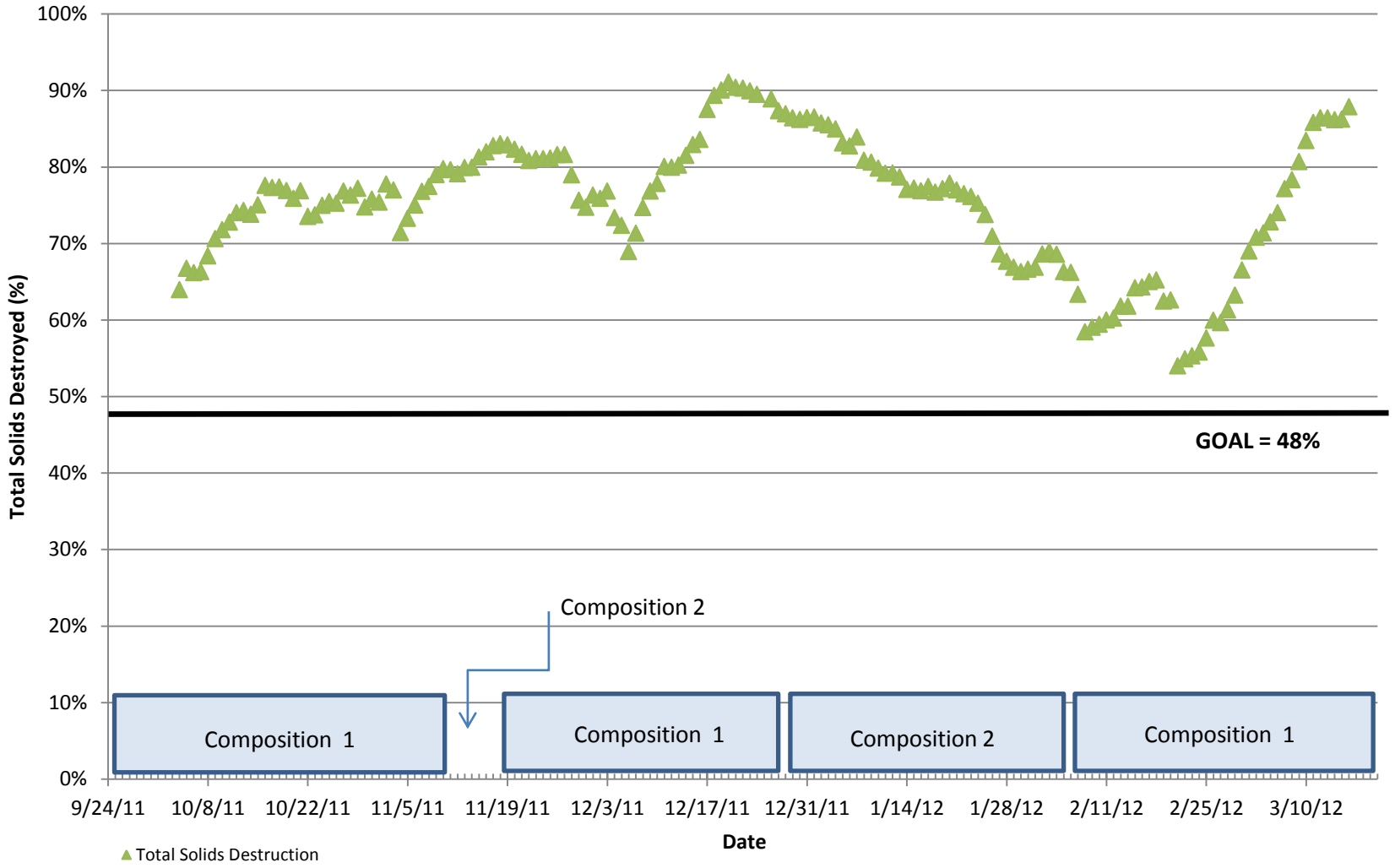
Volatile Solids Composition



Volatile Solids Destruction



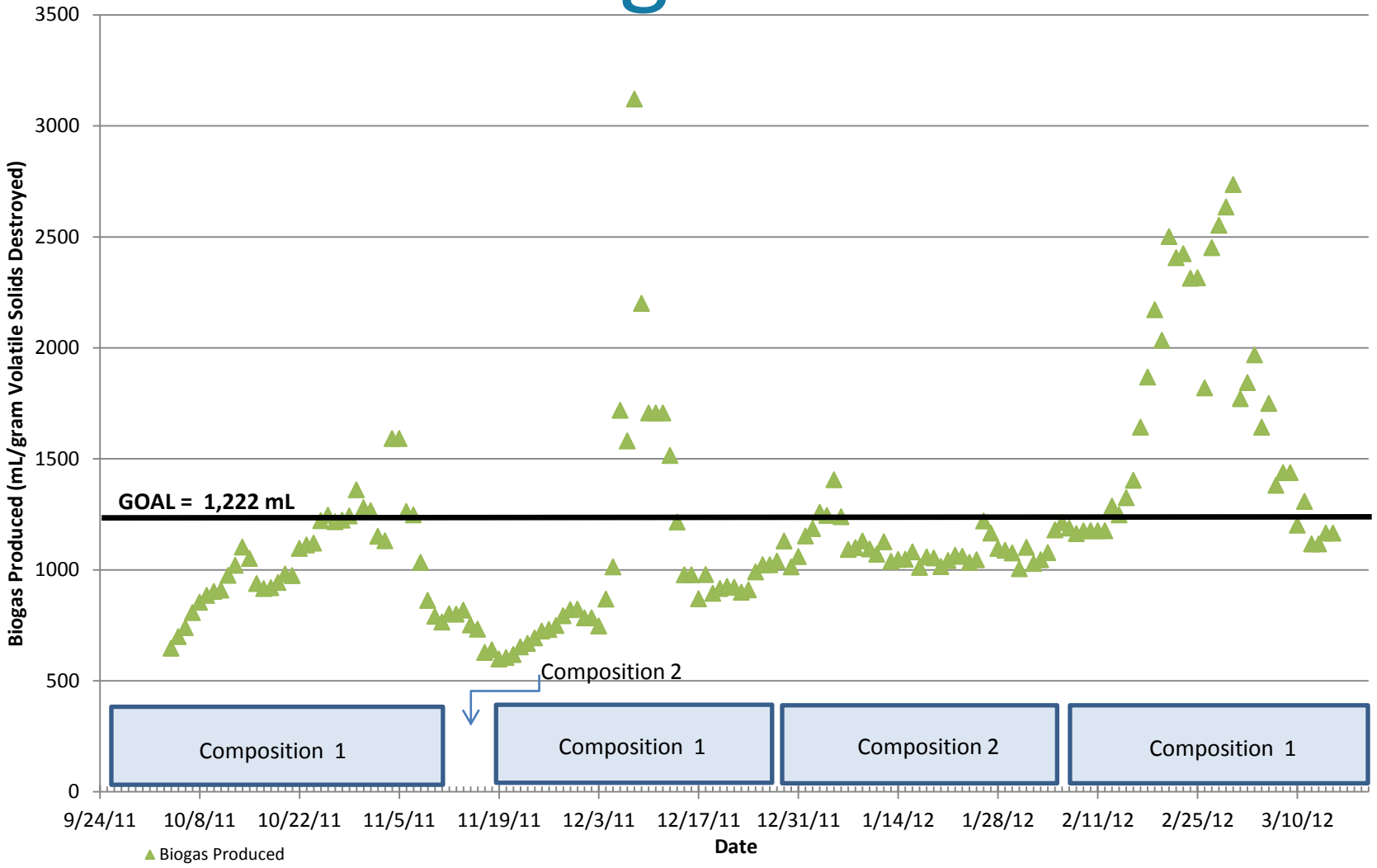
Total Solids Destruction



Biogas Production

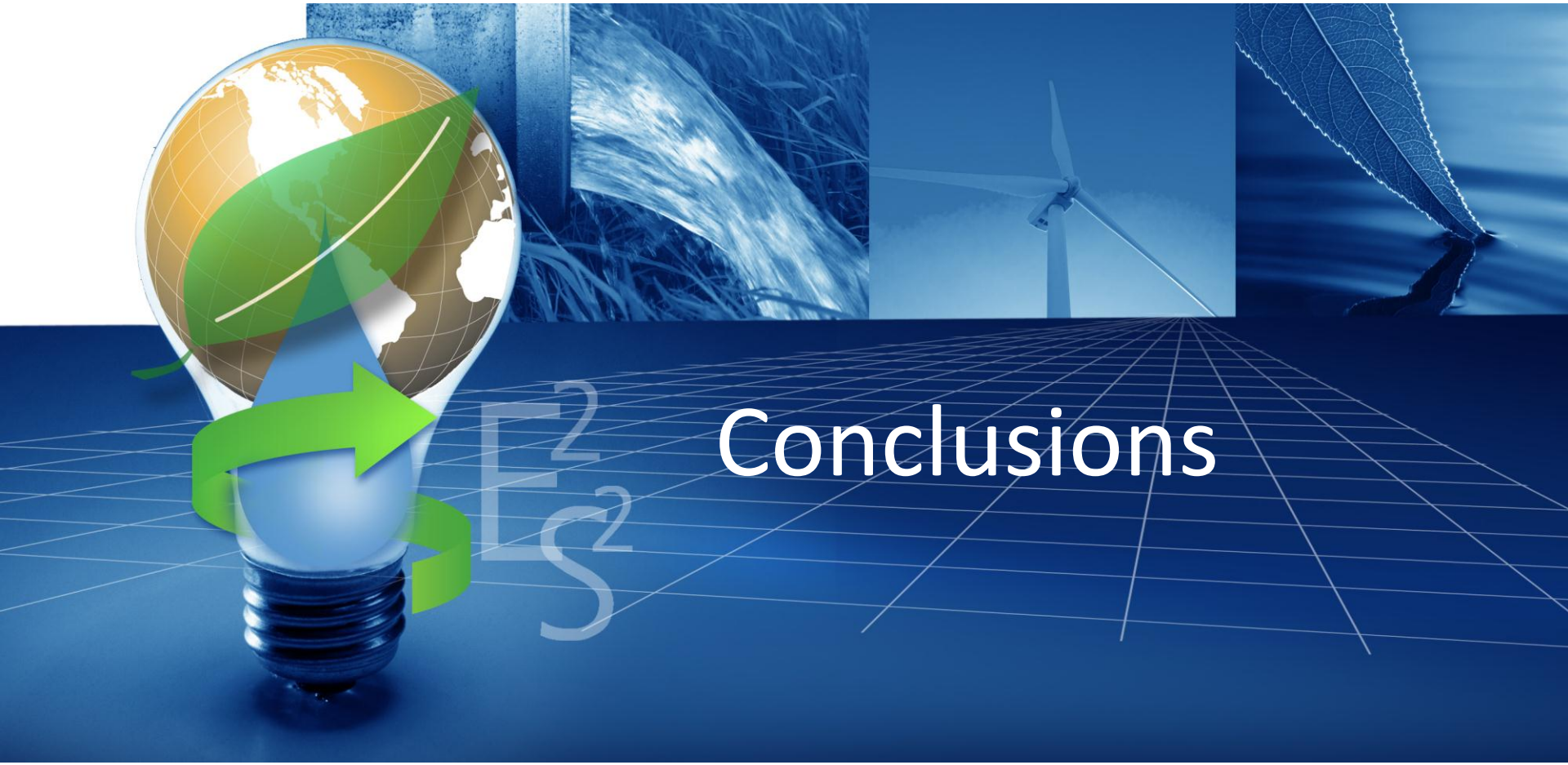
- Biogas contains methane = fuel source
- Biogas measured by flow meter
- Biogas generated was correlated to mass of volatile solids destroyed
- Biogas produced per unit of VS destroyed
  - Goal 1,222 ml/g VS destroyed
  - Composition 1 – 1,289 ml/g VS destroyed
  - Composition 2 – 1,076 ml/g VS destroyed
- Methane Content
  - Goal 70 %
  - Actual for Composition 1 – 55%
  - Actual for Composition 2 – 53%

mL of Biogas Produced



Operational Challenges

- Mass of Feedstock
- Mix Tank pH Stability
- Bioreactor Temperature
- Bioreactor Foaming
- Materials Processing
  - Mechanical/Pumping
  - Inert Material
- Biogas Measurement



Conclusions

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Research and Development Demonstration

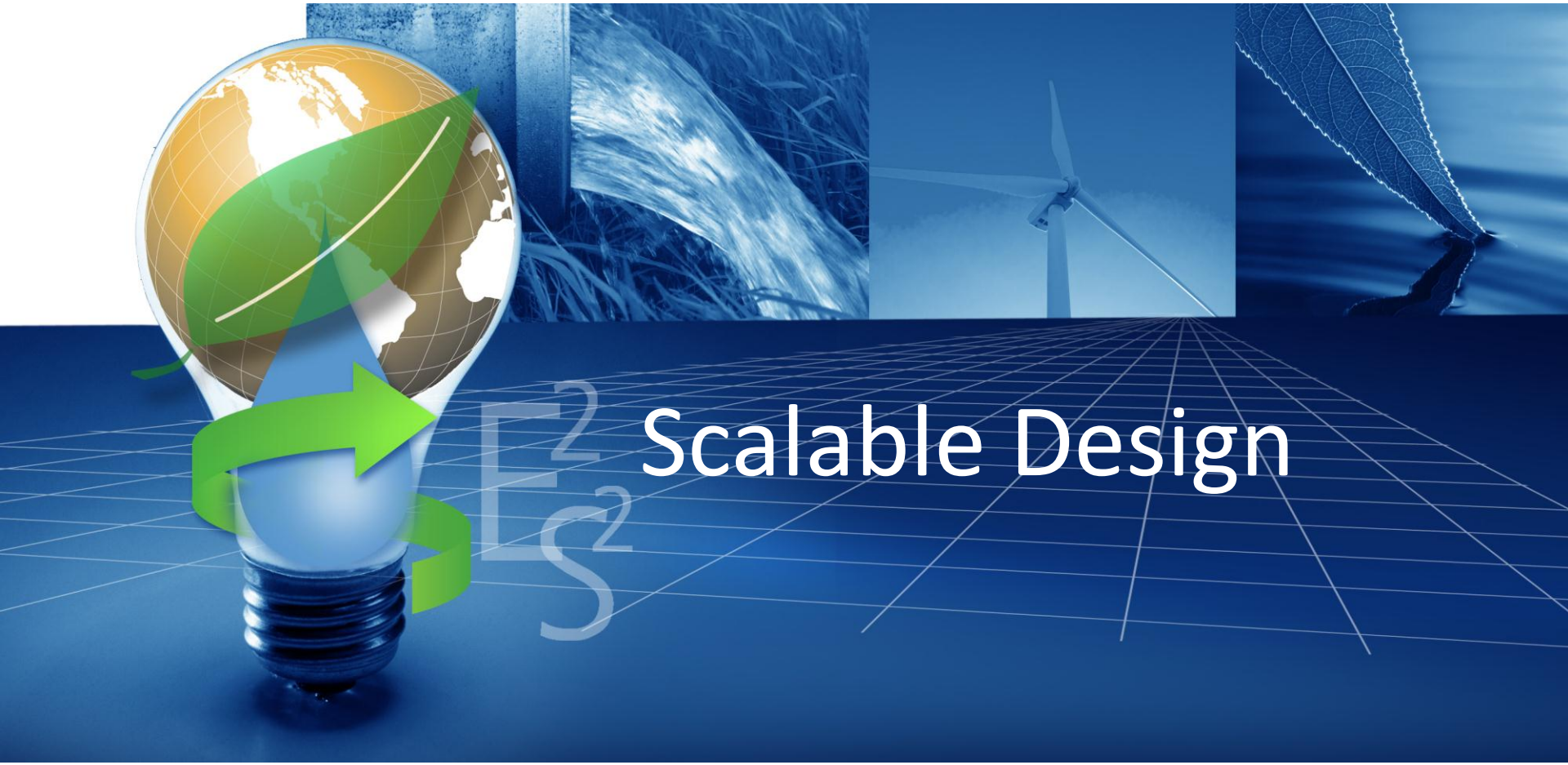
R&D ***successfully demonstrated***:

- Technology's ability to use organic waste to generate a renewable energy source
- Alternative to landfill
- Total and Volatile solids destruction
- Energy production met or exceeded target ranges
- Best feedstock - food waste and paper towels
- Design adaptations required for full scale
- Economic Evaluation ongoing - economics of full scale system dependent on available feedstock

Full Scale Design Sustainability Objectives

Ongoing activities for the marketable full-scale product

- ✓Further development of the Technology (continued R&D)
- ✓Confirm O&M cost for a full scale system
- ✓Scalable design criteria to enhance operation and biogas production
- ✓Applicability to larger scale
- ✓Verification of power generation using a microturbine
- ✓Refinement of the financial model and ROI for full scale



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Full Scale Design Objectives

- Maximize VSL / minimize reactor footprint
- Minimize equipment power consumption
- Minimize building footprint
- Maximize efficiency for MSW sorting
- Maximize biogas production/energy production
- Maximize waste application
- Maximize TS input to the HCAB
- Consider other applications, such as forward operating installations

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Imagine the result

Presenter: Scott Murphy, ARCADIS
Title: Waste to Energy Potential
Email: scott.murphy@arcadis-us.com